

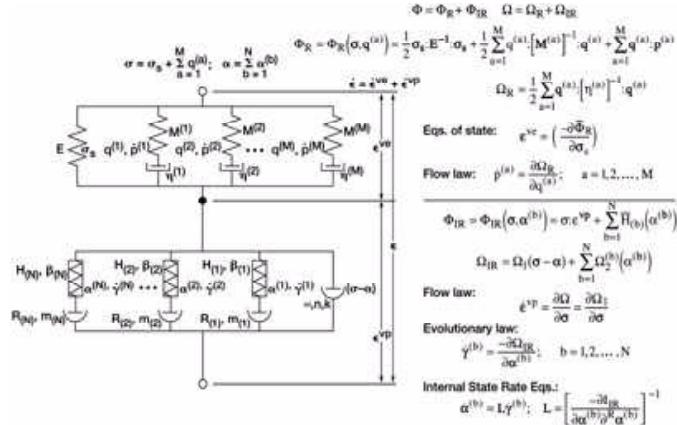
General Multimechanism Reversible-Irreversible Time-Dependent Constitutive Deformation Model Being Developed

Since most advanced material systems (for example metallic-, polymer-, and ceramic-based systems) being currently researched and evaluated are for high-temperature airframe and propulsion system applications, the required constitutive models must account for both reversible and irreversible time-dependent deformations. For example, considering that most aerospace engine designs are typically limited to the quasi-linear stress and strain regimes, the reversible time-dependent response component becomes dominant in comparison to the irreversible component. Alternatively, one can envision another extreme case (e.g., in polymer- and rubber-based systems under varying temperatures) in which a purely reversible viscous response is present. And lastly, an obvious natural extension for general applicability is the middle ground in which a combined reversible and irreversible representation is required. Furthermore, since an integral part of continuum-based computational methodologies (be they microscale- or macroscale-based) is an accurate and computationally efficient constitutive model to describe the deformation behavior of the materials of interest, extensive research efforts have been made over the years on the phenomenological representations of constitutive material behavior in the inelastic analysis of structures. From a more recent and comprehensive perspective (ref. 1), the NASA Glenn Research Center in conjunction with the University of Akron has emphasized concurrently addressing three important and related areas: that is,

1. Mathematical formulation
2. Algorithmic developments for updating (integrating) the external (e.g., stress) and internal state variables
3. Parameter estimation for characterizing the model

This concurrent perspective to constitutive modeling has enabled the overcoming of the two major obstacles to fully utilizing these sophisticated time-dependent (hereditary) constitutive models in practical engineering analysis. These obstacles are

1. Lack of efficient and robust integration algorithms
2. Difficulties associated with characterizing the large number of required material parameters, particularly when many of these parameters lack obvious or direct physical interpretations.



Recently, a coupled fully associative viscoelastoplastic model was formulated (refs. 1 to 4), with sufficient generality in its potential functions to permit systematic introduction of multiple mechanisms for both viscoelastic (reversible) and viscoplastic (irreversible) response components (see the figure). The notions of strain and stress partitioning have been introduced, leading to the additive decomposition of strain into reversible and irreversible parts, and the partitioning of the stress into

1. Its equilibrium (σ_s) and nonequilibrium ($q^{(a)}$) parts in the reversible region
2. The internal ($\alpha^{(a)}$) and overstress ($\sigma - \alpha$) components in the irreversible region

The viscoelastic part utilizes the concept of equilibrium stress, leading to a rate dependency upon instantaneous loading, as well as to a unique limiting state of elastic deformation for an infinite amount of time. The viscoplastic formulation accounts for both nonlinear kinematic hardening and static recovery submechanisms. This general, multimechanism, hereditary deformation model has been shown to accurately represent a wide spectrum of material response under different loading conditions for the case of titanium alloys. Examples include

1. Rate-dependent (effective) material tangent stiffness during initial loading or any subsequent reversed loading
2. Pure transient response (e.g., in creep or relaxation) within the reversibility region
3. Anelastic behavior upon stress reversal, irrespective of the load level
4. The many response features that are common to "unified viscoplastic" formulations already existing (e.g., rate-sensitivity, creep-plasticity interaction, and thermal recovery)

References

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